PRESSURE SENSOR, TRANSMITTER, AND TIRE CONDITION MONITORING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a pressure sensor, a transmitter that has the pressure sensor, and a tire condition monitoring apparatus that has the transmitter.

For example, Japanese Laid-Open Patent Publication No. 8-94468 discloses a structure of a pressure sensor unit, in which a pressure sensor is adhered to a lead terminal that also functions as a shielding member. The pressure sensor is three-dimensionally covered by the lead terminal. This structure prevents the pressure sensor from being affected by outside electromagnetic fields and thus allows the pressure sensor to accurately measure a pressure.

However, the pressure sensor is three-dimensionally covered with the lead terminal, which also functions as a shielding member. This increases the size of the pressure sensor unit. In other words, the structure of the publication cannot reduce a size of a pressure sensor unit that includes a shielding member.

SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a compact pressure sensor that accurately measures a pressure. The present invention also relates to a transmitter having such a pressure sensor and a tire condition monitoring apparatus having such a transmitter.

To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a pressure sensor having a diaphragm and metallic material is provided. The diaphragm is exposed to gas. The metallic material covers the diaphragm. A predetermined voltage can be applied to the metallic material.

The present invention also provides a transmitter having a pressure sensor that has a diaphragm exposed to gas. The transmitter transmits pressure data detected by the pressure sensor. The transmitter includes a power supply circuit, metallic material, and a connecting member. The power supply circuit supplies electricity to the transmitter. The metallic material covers the diaphragm. The connecting member connects the power supply circuit with the metallic material such that the potential of the metallic material is the same as the potential of the power supply circuit.

Further, the present invention provides a tire condition monitoring apparatus having a pressure sensor that measures air pressure in a tire of a vehicle, a transmitter that transmits pressure data measured by the pressure sensor, and a receiver that receives and processes data transmitted by the transmitter. The pressure sensor includes a diaphragm and metallic material. The diaphragm is exposed to air in the tire. The metallic material covers the diaphragm. The

transmitter includes a power supply circuit and a connecting member. The power supply circuit supplies electricity for activating the transmitter. The connecting member connects the power supply circuit with the metallic material such that the potential of the metallic material is the same as the potential of the power supply circuit.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a block diagram showing a tire condition monitoring apparatus according to one embodiment of the present invention;

Fig. 2 is a diagrammatic view showing the structure of one of the transmitters shown in **Fig. 1**;

Fig. 3 is a block diagram showing one of the transmitters shown in **Fig. 1**;

Fig. 4 is a schematic cross-sectional view showing the pressure sensor shown in **Fig. 3**;

Fig. 5 is a partially cross-sectional view showing the transmitter shown in **Fig. 3**;

Fig. 6 is a schematic cross-sectional view showing a pressure sensor according to another embodiment; and

Fig. 7 is a cross-sectional view showing a casing for accommodating a transmitter according to another embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A pressure sensor, transmitters, and a tire condition monitoring apparatus according to the present invention will now be described with reference to the drawings.

As shown in **Fig. 1**, the tire condition monitoring apparatus 1 includes four transmitters **30** and a receiver **40**. Each transmitter **30** is located in one of the tires **20** of a vehicle **10**. The receiver **40** is located on a body frame **11** of the vehicle **10**.

Each transmitter **30** is located in the corresponding tire **20** and is fixed, for example, to a wheel **21** of the tire **20**. Each transmitter **30** measures the condition of the corresponding tire **20**, that is, the pressure of the tire **20**. The transmitter **30** then wirelessly transmits data containing air pressure data.

The receiver **40** is located at a predetermined position on the body frame **11** and is activated by electricity of a battery (not shown) of the vehicle **10**. The receiver **40** includes a single reception antenna **41**. The reception antenna **41** is connected to the receiver **40** with a cable **42**. The receiver **40** receives data transmitted by the transmitters **30** through the reception antenna **41**.

A display **50** is located in the view of the driver of the vehicle **10**, for example, in the passenger compartment. The display **50** is connected to the receiver **40** with a cable **43**.

As shown in **Fig. 2**, each transmitter **30** is accommodated in a casing **70**, that is located below a valve stem **60**. Air is injected into the tire **20** through the valve stem **60**. The casing **70** is substantially formed into a rectangular box. The casing **70** accommodates a substantially rectangular substrate **80**. Electronic elements such as transmission controller **31**, a pressure

sensor **32**, a transmission circuit **33**, a transmission antenna **34**, and a battery **35** are mounted on the substrate **80**. The substrate **80** is fixed to bosses **71** that are integrally formed with the casing **70**. The casing **70** has a through hole (not shown) to permit the pressure sensor **32** to measure the air pressure in the tire **20**. The casing **70** has an opening **72**, which is closed with a lid (not shown) for protecting the electronic elements.

As shown in **Fig. 3**, each transmitter **30** includes a transmission controller **31**, which is a microcomputer. The transmission controller **31** includes, for example, a central processing unit (CPU), a read only memory (ROM), and a random access memory (RAM). A unique ID code is registered in an internal memory, for example, the ROM, of the transmission controller **31**. The ID code is used to distinguish the associated transmitter **30** from the other three transmitters **30**.

The pressure sensor **32** measures the air pressure in the interior of the associated tire **20** and provides the transmission controller **31** with pressure data, which is obtained from the measurement. The transmission controller **31** sends data containing the air pressure data and the registered ID code to a transmission circuit **33**. The transmission circuit **33** encodes and modulates the data sent from the transmission controller **31**. The transmission circuit **33** then wirelessly sends the data through a transmission antenna **34**. The transmitter **30** is provided with a battery **35**. The transmitter **30** is driven by electricity of the battery **35**.

As shown in **Fig. 4**, the pressure senor **32** is made of ceramic, and has an upper base **100** and a lower base **200**. A metallic material film **101** is formed on the outer surface of the upper base **100**. A frustoconical recess **102** is formed in a central portion of the upper base **100**. As a result, a diaphragm **103** is formed in an central upper portion of the upper base **100**. A first inner

electrode **104** is formed on the lower surface of the diaphragm **103**.

A second inner electrode **201** is formed in a center of the upper surface of the lower base **200**. The metallic material film **101**, the first inner electrode **104**, and the second inner electrode **201** are formed by aluminum deposition. The upper base **100** and the lower base **200** are hermetically attached to each other such that the first inner electrode **104** and the second inner electrode **201** face each other. As a result, a hermetic space **105** is defined between the first inner electrode **104** and the second inner electrode **201**. The hermetic space **105** is filled with gas having a predetermined pressure.

The metallic material film **101**, which covers the diaphragm **103**, is exposed to the air inside the tire **20** through the through hole (not shown) formed in the casing **70**. In other words, the metallic material film **101** is exposed to air, which is a measured gas. Therefore, when the air pressure in the tire **20** changes, the difference between the air pressure in the tire **20** and the pressure of the gas filling the hermetic space **105** is changed. Accordingly, the diaphragm **103** is flexed. Then, the distance between the first inner electrode **104** and the second inner electrode **201**, which changes a capacitance between the first inner electrode **104** and the second inner electrode **201**, accordingly. Therefore, the air pressure in the tire **20** is measured based on the capacitance between the first inner electrode **104** and the second inner electrode **201**. That is, the pressure sensor **32** is a capacitance type pressure sensor.

As shown in **Fig. 5**, the metallic material film **101** on the upper base **100** is connected to the battery **35** with a lead wire **300** and traces of the wiring pattern on the substrate **80**. The lead wire **300** and the traces function as connecting means. Specifically, the metallic material film

101 is connected to a power supply potential Vdd (+3V) or a ground potential GND (0V) of the battery **35**. As a result, the metallic material film **101** on the upper base **100** is maintained to the same potential as the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35**. The ground potential GND (0V) of the battery **35** is connected to a ground potential GND of the transmission circuit **33**. The battery **35** and the transmission circuit **33** function as a power supply circuit that supplies electricity to the transmitter **30**.

This embodiment has the following advantages.

(1) The metallic material film **101** is formed on the outer surface of the upper base **100** to cover the diaphragm **103**. The metallic material film **101** on the upper base **100** is connected to the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35** with the lead wire **300** and the traces on the substrate **80**. Accordingly, the metallic material film **101** on the upper base **100** is maintained to the same potential as the potential of the battery **35**. As a result, the first inner electrode **104** and the second inner electrode **201** of the pressure sensor **32** are shielded by the metallic material film **101**. This structure prevents the pressure sensor **32** from being affected by outside electromagnetic fields and thus allows the pressure sensor **32** to accurately measure the air pressure in the tire **20**. Unlike the structure disclosed in Japanese Laid-Open Patent Publication No. 8-94468, where the pressure sensor is three-dimensionally covered with a lead terminal that also functions as a shielding member, the metallic material film **101** on the upper base **100** is connected to the ground potential GND on the substrate **80** with the lead wire **300**. Therefore, the size of the pressure sensor **32** is reduced.

(2) Since the size of the pressure sensor **32** is reduced, the size of the transmitter **30** is

reduced. Therefore, when attaching the tire **20** to the wheel **21**, the bead of the tire **20** is prevented from contacting the casing **70**, which accommodates the transmitter **30**. Therefore, when attaching the tire **20**, the casing **70** and the transmitter **30** are not damaged.

(3) The pressure sensor **32** is scarcely affected by outside electromagnetic fields. This permits the pressure sensor **32** to accurately measure even small changes in the air pressure in the tire **20**. Therefore, the transmitter **30** wirelessly transmits accurate air pressure data to the receiver **40**.

(4) The receiver **40** receives data through the reception antenna **41** and, based on the received data, causes the display **50** to display air pressure data. This informs a driver of the vehicle **10** of the accurate air pressure data. In other words, the present invention provides the tire condition monitoring apparatus **1**, which accurately measures the air pressure in the tire **20**.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

The metallic material film **101** on the upper base **100** may be directly connected to the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35** with the lead wire **300**, without using the traces on the substrate **80**.

As shown in **Fig. 6**, the metallic material film **101** on the upper base **100** may be connected to the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35** with the traces on the substrate **80** and a tungsten plated through hole **400**.

As shown in **Fig. 7**, a conductor **500** having bent ends may be provided on a lid **73** of the casing **70**. The metallic material film **101** on the upper base **100** may be connected to the battery **35** (for example, a positive terminal) with the conductor **500** when the opening **72** is closed with the lid **73**. In this case, the shielding effect is obtained only by closing the opening **72** of the casing **70** with the lid **73** with the conductor **500**. Compared to conventional assembly procedure, only a step for attaching the conductor **500** to the lid **73** is added. In other words, no complicated step is added to the procedure for obtaining the shielding effect. Thus, with the structure of the lid **73** having the conductor **500**, the transmitter **30** is easily assembled with the casing **70**.

In the illustrated embodiment, the metallic material film **101** is formed on the entire upper surface of the upper base **100**. However, the metallic material film **101** may be formed on a part of the upper surface of the upper base **100** to cover the diaphragm **103**. That is, the metallic material film **101** may be formed only on a center portion of the upper surface of the upper base **100**.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.